

Review Article

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Nutritional Security Options through Agronomic Bio-fortification of Zinc and Iron in Chickpea under Rainfed Areas for Poor and under Nourished Masses of South East Asia-A Review

Brij Nandan*, B. C. Sharma, Gurdev Chand, Akhil Verma,
Kapilashiv Bazgalia and Rakesh Kumar

PRSS, AICRP on Chickpea, SKUAST-Jammu, Samba 184121, India

*Corresponding author

ABSTRACT

Unlike plants, humans also require essential micronutrients and protein for normal physiological functions of the body and general health. Due to low concentration of micronutrients and protein in the staple food, billions of population is lacking sufficient daily intake of micronutrient and protein in their diet sometimes called 'hidden hunger'. Micro nutrient malnutrition is a serious problem to human health throughout the world, primarily in resource limited countries. The micronutrients most commonly associated with human health problems on a global scale include iron, zinc and iodine. Humans require at least 22 mineral elements for their wellbeing. These can be supplied by an appropriate diet. However, it is estimated that over 30 percent of population is zinc (Zn) deficient and rest with other micronutrients. Among micronutrients, Zn deficiency is occurring in both crops and humans. Zinc deficiency is currently listed as a major risk factor for human health and cause of death globally. According to an estimate of World Health Organization (WHO) during 2015, around two billion people are being suffered with iron and zinc deficiencies and its deficiency ranks 11th among the 20 most important factors in the world and 5th among the 10 most important factors in developing countries like India. Zn deficiency is widespread in chickpea growing region of the world and is most prevalent among the micronutrients. In the sequence of micronutrient malnutrition; iron is also playing a vital role. Its deficiency is a highly prevalent nutritional disorder afflicting 2.5 to 5 billion people around the globe where poor households and pre-school children are severely affected due to high demand for iron. Iron acts as a co-factor for several enzymes performing basic functions in human body. Inadequate supply of iron contributes to disability, anemia and stunted mental growth.

Keywords

Fortification,
Zinc, Iron,
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Introduction

Globally the *rainfed* region over about 40 percent of the world's land area and host nearly 40 percent of the world's population. Of the 1.5 billion hectare (11 percent of the world's land surface of 13.4 billion ha) of

cropland worldwide, 1.223 billion hectare (82 percent) is *rainfed* (FAO, 2015). Further, about 70 percent of the world's staple food continues and will continue to be harvested from *rainfed* areas, since the scope for further expansion of irrigation is limited due to growing competition for water and the high

investment cost. The importance of *rainfed* agriculture varies regionally, and is most significant in Sub-Saharan Africa, where it accounts for about 93 percent of farmed land, 87 percent in Latin America, 67 percent in the Near East and North Africa, 65 percent in East Asia and 58 percent in South Asia (Anon, 2009). Most countries depend primarily on *rainfed* agriculture for their foodgrain. About 30 percent of the world's land surface (4.2 billion hectares) is suitable for *rainfed* agriculture. Therefore, upgrading *rainfed* agriculture promises large social, economic and environmental paybacks, particularly in poverty reduction and economic development. India ranks first among the *rainfed* countries in the world in terms of area, but counts amongst the lowest in *rainfed* yields (<1 ton/ha). As high as 78 million hectare accounting for 64 per cent of the country's net sown area is *rainfed* (Anonymous, 2017) contributing 44 percent of the total foodgrain production. It is estimated that even after achieving the full irrigation potential; nearly 50 percent of the net cultivated area will remain dependent on rainfall. Cultivation of coarse cereals (91 percent), pulses (91 percent), oilseeds (80 percent) and cotton (65 percent) predominates in these *rainfed* regions (CRIDA, 2007). In the state of Jammu and Kashmir, *rainfed* agriculture is practiced over an area of 4.26 lakh hectares which represents 57.64 per cent of the net sown area of 7.39 lakh hectares in the state. Further, out of the total culturable area of 3.90 lakh hectares in Jammu region 75.25 per cent is *rainfed* and needs to be judiciously for higher water use efficiency (Nandan *et al.*, 2012). Pulses are produced on 12-15 percent of global arable land and their contribution to total human dietary protein nitrogen requirement is 30%. Most important dietary pulses include chickpea, beans, lentil, green gram (mungbean), black gram (urbean) field peas, pigeonpea, and cow pea and are also used as protein supplements. The

global pulse production, area and yield during 2013 was 73 million tonnes, 80.8 million hectare and 904 kg /ha, respectively (FAOSTAT 2015). India ranks first in the world's production and area by contributing around 70 percent to the world's total pulses production. Among the different pulses, chickpea is grown in over 40 countries across five continents. India is the leading producer of chickpea accounting for nearly 65.78 and 67.35 percent of the total area (8.52 million hectares) and production (8.83 million tons), respectively (Anonymous, 2015). In the state of Jammu and Kashmir, total area under chickpea is 4 thousand hectares with a production and productivity of 2.51 thousand tones and 6.27 quintals/ha, respectively (Anonymous, 2012-13). It is one of the most important food legume plants in sustainable agriculture system because of its low production cost, wider adaptation, ability to fix atmospheric nitrogen and fit in various crop rotations. It is a rich source of quality protein (20-22 percent) to the predominantly vegetarian population in Indian subcontinent. It has the highest nutritional compositions and free from anti-nutritive components compared to any other dry edible grain legumes, thus, it is considered a functional food or nutraceutical. Besides proteins, it is rich in fiber and minerals (phosphorus, calcium, magnesium, iron and zinc), and its lipid fraction is high in unsaturated fatty acids and has no anti- nutritional factors, and contains higher amounts of carotenoids like β -carotene than genetically engineered 'Golden rice' (Sandhu *et al.*, 2015).

Unlike plants, humans also require essential micronutrients and protein for normal physiological functions of the body and general health. Due to low concentration of micronutrients and protein in the staple food, billions of population is lacking sufficient daily intake of micronutrient and protein in their diet sometimes called '*hidden hunger*'

(Thavarajah and Thavarajah, 2015; Singh *et al.*, 2015a). Micro nutrition malnutrition is a serious problem to human health throughout the world, primarily in resource limited countries (Kennedy *et al.*, 2003). The micronutrients most commonly associated with human health problems on a global scale include iron, zinc and iodine. Humans require at least 22 mineral elements for their wellbeing (Welch & Graham, 2004; White & Broadley, 2005; Graham *et al.*, 2007). These can be supplied by an appropriate diet. However, it is estimated that over 30 percent of population is zinc (Zn) deficient and rest with other micronutrients. Among micronutrients, Zn deficiency is occurring in both crops and humans (Hotz and Brown, 2004; Welch and Graham, 2004; Shively *et al.*, 2014a). Zinc deficiency is currently listed as a major risk factor for human health and cause of death globally. According to an estimate of World Health Organization (WHO) during 2015, around two billion people are being suffered with iron and zinc deficiencies and its deficiency ranks 11th among the 20 most important factors in the world and 5th among the 10 most important factors in developing countries like India. Zn deficiency is widespread in chickpea growing region of the world and is most prevalent among the micronutrients. In the sequence of micronutrient malnutrition; iron is also playing a vital role. Its deficiency is a highly prevalent nutritional disorder afflicting 2.5 to 5 billion people around the globe (Yip, 2002) where poor households and pre-school children are severely affected due to high demand for iron (Benoist *et al.*, 2008). Iron acts as a co-factor for several enzymes performing basic functions in human body. Inadequate supply of iron contributes to disability, anemia and stunted mental growth (Sheftela *et al.*, 2011). Malnutrition of above mentioned nutrients is more prevalent in Asian countries where cereals are staple food. In contrast to food security, nutrition security

has traditionally been viewed as being within the realm of health professionals. Yet the entire agri-food chain has a vital role to play in addressing this problem. Producing more nutritious food and feed, or ‘*farming for health*’, should therefore be a central objective.

Therefore, with this backdrop, there is need to disseminate the different Agronomic Biofortification options for nutritional security. In this context an attempt has been made to compile the information and to put forth in front of the researchers and professional academicians to propagate the same to the ultimate users.

Materials and Methods

Extensive studies have been conducted to collect the review of literature on the Zn and Fe fortification and after getting the enough literature the literature is divided into two main headings with Zinc and iron fortification effects on different growth, development, yield and quality parameters of chickpea and allied pulse crops. The each Zinc and Iron components are subdivided into eight sub headings in which the literature is arranged. An attempt has been made to review the effect of foliar nutrition and its impact on nutritional security for more than three decades literature. The extensive survey of library and internet able to collect the results of different scientist and an attempt has been made to compile it for the use of the researchers across the globe

Effect of zinc fertilization on

Effect of zinc fertilization on growth parameters
Effect of zinc fertilization on plant height of chickpea cultivars
Effect of zinc fertilization on leaf area index of chickpea cultivars

Effect of zinc fertilization on dry matter accumulation of chickpea cultivars

Effect of zinc fertilization on physiological parameters

Effect of zinc fertilization on yield and yield attributes of chickpea cultivars

Effect of zinc fertilization on quality parameters

Effect of zinc fertilization on relative economics

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Results and Discussion

The results of the study are presented in the following heads with proper justification (Fig. 1)

Effect of zinc fertilization on

Effect of zinc fertilization on growth parameters

Nourishment of mother plant with balanced nutrition particularly nitrogen, phosphorus and potassium could help proper crop growth, development and cause for exhibiting the potential growth. Increasing levels of fertilizers progressively enhances not only the growth attributes but also seed and stover

yield and NPK uptake by seed and stover.

Effect of zinc fertilization on the plant height of chickpea cultivars

Field experiment conducted by Habbasha *et al.*, (2013) while working in Egypt, to access the effect of foliar application of Zinc at different growth stages in chickpea crop and reported a significant increase in plant height of chickpea over the control treatments. It was reported that application of nitrogen levels in combination with Zn as foliar application either at flowering or seed filling stages exhibited significant increases in most of the growth characters as compared to without Zn application. Hadi *et al.*, (2013), while studying the effects of zinc application on yield and yield components of Chickpea also reported that zinc had positive effects on plant height. Studies conducted by Kayan *et al.*, (2015), in Turkey, under dryland conditions, to determine the effect of foliar application of zinc on the yield of chickpea crop, reported a significant difference in growth parameters like plant height of chickpea. Hossain *et al.*, (2016), while working on sandy loam soils Bangladesh, to study the effect of boron and zinc on the growth and yield of chickpea noticed that zinc showed significant effect on plant height of chickpea.

In a study conducted by Sajid *et al.*, (2016) to access the influence of zinc fertilization in vegetable crop revealed that highest plant height was observed in plants that receive zinc foliar spray as compared to the control plants where no zinc was applied. In contrast to above findings, El- Tohamy *et al.*, (2009) reported that plant height of vegetable crop significantly increased by the application of Zn as compared to control plants.

Effect of zinc fertilization on the leaf area index of chickpea cultivars

Experiments conducted by Jha *et al.*, (2015) on clay loam soils of Udaipur, recorded

highest leaf area index with treatment where zinc was applied as foliar spray as compared to the rest of the treatments. Studies conducted by Sajid *et al.*, (2016), at Peshawar, to access the influence of zinc fertilization revealed that more number of leaves were observed in plants where zinc was applied as foliar spray as compared to the control plants. In contrast to above findings, Yousaf *et al.*, (2007) who found that zinc foliar application significantly enhanced the leaf area index. Similarly, Alam *et al.*, (2010) found the response of micronutrients for vegetable crop leaf area index are significantly influenced by the application of Zn.

Effect of zinc fertilization on the dry matter accumulation of chickpea cultivars

Enania *et al.*, (1994) while working on calcareous soils of Udaipur, reported the application of 5.0 and 7.0 kg Zn/ha significantly increased the dry matter of chickpea by upto 6.87 and 7.34 g/plant respectively over control and 2.5 kg Zn/ha as dry matter of 5.92 and 6.37 g/plant respectively. Experiments was conducted by Khan *et al.*, (2003), in Australia, to access the effect of zinc fertilization in chickpea crop and reported that there was a significant increase in dry matter production with application of zinc. Field experimentation on sandy loam soils of Bikaner conducted by Balai *et al.*, (2017), to access the influence of zinc fertilization and found that increasing dose of zinc up to 6 kg/ha significantly increased the dry matter accumulation at 60, 90 and 120 DAS over the control treatment. Jha *et al.*, (2015) while working on clay loam soils of Udaipur recorded significantly higher dry matter accumulation by the application of zinc over the rest of the treatments. Hossain *et al.*, (2016) conducted study on sandy loam soils of Bangladesh and found that dry matter accumulation increased with the application of zinc over the control treatments.

Effect of zinc fertilization on physiological parameters

Study was carried out by Ingle *et al.*, (2016), to determine the “Effect of foliar application zinc and iron on growth yield and quality of gladiolus grown on Vertisol”, during Rabi season 2013-14 at Bhajiwadi of Horticulture, College of Agriculture, Nagpur (Maharashtra), India. The experiment was laid out in FRBD with three replication consistent four levels of zinc and iron viz., Zn₀-1 (water spray) Zn₁- 0.5%, Zn₂- 1.0%, Zn₃-1.5% and Fe₀- (water spray), Fe₁- 0.5%, Fe₂- 1.0% and Fe₃- 1.5%. The result showed that days required for first spike emergence in gladiolus was significantly influenced by application of various levels of zinc and the treatment Zn₂ took required significantly minimum days (63.17 days) for emergence, which was of first spike and it found statistically at par with the treatments Zn₁ (67.83 days) and the treatment Zn₃ (66 days). Whereas, the treatment Zn₀ took maximum days for emergence of first spike (71.25 days). Application of zinc resulted in early in flowering in gladiolus and the first spike emergence was noted with application 1.0% zinc, which might be due to the fact that, zinc plays vital role in growth and development of plant because of its stimulatory and catalyst effect in various physiological and metabolic process of plan. Experiment was carried out by Sajid *et al.*, (2016), at New Developmental Farm (NDF) Horticulture section Khyber Pakhtunkhwa, Agricultural University Peshawar, during summer 2011 to study the influence of zinc as soil and foliar application on growth and yield of *okra*. The data on number of days to 50% flowering indicated that significant differences were observed in *okra* with different levels of zinc, methods of application as well as their interaction. The highest number of days (51.5days) to 50% flowering was observed in plots where zinc was applied as soil while the foliar application of zinc resulted in earlier 50% flowering

(50.1days). The flowering delayed (51.2days) in control plants (untreated with zinc) and it was at par with the plots each received zinc at the rate of 4, 6, and 8 kg/ha but statistically different from plots where zinc applied at the rate of 2 kg/ha, where earlier flowering occur (49.83).

Effect of zinc fertilization on the yield and yield attributes of chickpea cultivars

Kushwaha (1997) showed that application of zinc sulphate at 25 kg/ha increased the productivity upto 22.2 per cent over the control in chickpea. Sakal *et al.*, (1998) found that application of zinc progressively increased the grain yield of chickpea from 14.5 to 19.0 q/ha and straw yield from 16.0 to 22.0 q/ha. The grain yield response ranged between 150 to 450 kg/ha as zinc dose increased from 2.5 to 10 kg/ha. Zinc @ 5 kg was found as ideal dose for chickpea. Brennan *et al.*, (2001) reported that the relative response of chickpea to Zn application is greater than that of other crops. Zn application resulted in more vegetative growth, leading to greater yield. Experiments was conducted by Khan *et al.*, (2003) in Australia, to assess the effect of Zinc fertilization in chickpea crop and reported that there was a significant increase in grain yield with the application of zinc when there was adequate moisture. They also found that application of Zinc resulted in improved water use efficiency in chickpea crop. Field experiments were conducted by Sangwan *et al.*, (2004), during *rabi* seasons at Dryland Research Farm of CCS Haryana Agricultural University, Hisar located in an arid climate to evaluate the effect of Zn appreciation to soil (0, 5, 10 and 15 kg Zn/ha) on chickpea yield under dryland conditions. It was reported that the grain yield of chickpea increased significantly with various levels of Zn application when compared with the control. The result also showed that a mean grain

yield increase of 35% was observed with zinc fertilization over control. Valenciano *et al.*, (2010) conducted an experiment on loamy soil conditions of Spain, to evaluate the response of Zinc application on chickpea crop under pot condition, and the results showed that application of zinc enhances yield attributes viz; pods/plant, 1000-seed weight and finally the seed yield of Chickpea. It was also observed that the soil application of Zn increases growth due to increase in dry weight of pods including seeds. The lowest plant yield was obtained when the Zn application was not carried out (2.55 g/plant). Chickpea yield increased with the incremental increase in the application of Zn to until Zn₄ (3.23 g/plant). Ramaprasad *et al.*, (2011) revealed that soil application of 25 kg ZnSO₄/ha along with 0.5% ZnSO₄ foliar spray of twice (45 and 55 DAS) proved significantly superior over the control in seed yield (3046 kg/ha) in *kabuli* chickpea under clay loam soils of Andhra Pradesh. Study carried out by Valenciano *et al.*, (2011) in the province of Leon, Spain, under the field conditions, with the aim of determining whether the application of Zinc (Zn) improved chickpea growth and yield. The results showed that, at maturity, plants fertilized with Zn had a greater total dry matter production and seed yield, mainly due to increment in pod dry matter. Shaban *et al.*, (2012) conducted a field experiment on clay soil, in Bu-Ali Sina University of Hamedan, Iran, to determine the effects of Zinc fertilizer on yield and yield components of chickpea. It was found that application of Zinc fertilizer had better effect on grain yield, yield components and biomass yield increased with application of it significantly. Among the Zn fertilizer treatments, the highest grain yield (3526 kg/ha) was belonged to the Zn₁ treatment and the lowest grain yield (3125kg/ha) was belonged to the Zn₀ treatment. A field experiment was conducted by Parimala *et al.*, (2013), at Seed Research and Technology

Centre, Rajendranagar, Hyderabad (A.P.), India to study the effect of macro and micronutrients on yield and seedling quality parameters of chickpea variety JG-11. The result showed that Zn (0.5%) enhanced the number of pods/plant and led to maximum seed yield/plant compared to all other treatments. Application of zinc enhanced the root growth, nodulation and nitrogen content of nodules indirectly contributing to the increased yield. Pooniya and Shivay (2012) carried out a field experiment during the rainy season of 2008 and 2009 at a research farm of the Indian Agricultural Research Institute, New Delhi on study the effects of summer green-manuring crops and zinc (Zn) fertilization on the productivity and economics of basmati rice with four treatments comprising summer green-manuring residue incorporation and eight treatments of Zn fertilization, i.e. absolute control (no N and no Zn), control (only N), 2.0% Zn-enriched urea (ZEU) ($\text{ZnSO}_4 \cdot \text{H}_2\text{O}$), 2.0% ZEU (ZnO), 5 kg Zn/ha ($\text{ZnSO}_4 \cdot \text{H}_2\text{O}$) as soil application, 5 kg Zn/ha (ZnO) as soil application, ZnO slurry for dipping rice seedling roots before transplanting of basmati rice and 0.2% foliar spray of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ at maximum tillering, pre-flowering and flowering stage and reported that significant increase in plant height due to Zn fertilization in both years. The highest plant height, high number of tillers and higher dry matter accumulations at 30, 60 and 90 days after transplanting was observed with 2.0% ZEU ($\text{ZnSO}_4 \cdot \text{H}_2\text{O}$) in 2008 and 2009, respectively. Conducted studies by Pathak *et al.*, (2012), in Lucknow, reported an increase in grain yield of chickpea due to Zn application. Foliar application of ZnSO_4 to zinc deficient plants at the time of initiation of flowering partially reverses the adverse effect of zinc deficiency on pollen-stigma morphology, pollen fertility, and greatly enhanced seed yield of plants. It was reported that in comparisons with the plants given low Zn supply, the number and

weight of pods and seeds formed was high in plants given sufficient Zn supply. Habbasha *et al.*, (2013) while working in Egypt, studied the effect of foliar application of Zinc at different growth stages in chickpea crop and reported a significant increase in number of pods/plant, weight of pods/plant, seed yield /plant, seed and straw yields. It was reported that application of nitrogen levels in combination with Zn as foliar application either at flowering or seed filling stages exhibited significant increases in most of the growth characters as compared to without Zn application. Hadi *et al.*, (2013) while studying the effects of zinc application on yield and yield components of Chickpea also reported that zinc had positive effects on seed yield. In a study conducted by Kharol *et al.*, (2014) to study the effect of sulphur and zinc on yield, quality and nutrient content and uptake by chickpea (*Cicer arietinum* L.) was conducted during rabi season of 2011-12 at the instructional Farm of R. C. A., Udaipur with four levels of sulphur (0, 15, 30 and 45 kg S/ha) and zinc (0, 2.5, 5.0 and 7.5 kg Zn/ha). It was observed that the maximum number of branches per plant (22.22) was observed with the application of 7.5 kg Zn/ha but it was found at par with 5 kg Zn/ha. The test weight of grain (g) increased significantly up to 5 kg Zn/ha which was at par with 7.5 kg Zn/ha. It was significantly superior to rest of the zinc levels. Application of 5 kg Zn/ha significantly increased seed yield over control and 2.5 kg Zn/ha by 25.20 and 12.55%, respectively. The effect of application of 5 and 7.5 kg Zn/ha was found at par. Studies was conducted by Shivay *et al.*, (2014) at IARI, New Delhi, to study the effect of varieties and levels of Zinc (Zn) application on the grain yield in chickpea (*Cicer arietinum* L.) and reported significant enhancement in growth characters. The result showed that with each successive increase in the application of Zn from 2.5 to 7.5 kg/ha also increased the grain as well as straw yields of chickpea. Zn application

significantly improved yield attributes, grain and straw yields. The study also brings out that Zinc application not only increases the grain yield in chickpea but as leads to Zn fortification of grains. Field experiment was conducted by Shivay *et al.*, (2014), at the Indian Agricultural Research Institute, New Delhi, to study the effect of genetic variability and Zinc use efficiency in Chickpea as influenced by Zinc fertilization and the result showed that with each successive increase in the application of Zn from 2.5 to 7.5 kg/ha also increased the grain as well as straw yields of Chickpea. However, the significantly highest grain yield (2.24 t/ha, mean of 2 years) was recorded with application of 7.5 kg Zn/ha which was 18.52, 1089 and 4.19% higher compared to 0, 2.5 and 5.0 kg Zn/ha respectively. Alam and Kumar (2015) studied on effect of zinc on growth and yield of at Saran district of Bihar with four treatments (0 kg/ha ZnSO₄, 05 kg/ha ZnSO₄, 10 kg/ha ZnSO₄ and 20 kg/ha ZnSO₄) and show that the highest growth parameters included plant height (cm), plant dry weight (g), number of tillers/m², number of effective tillers/m² with application of 10 kg/ha ZnSO₄. It has been reported that higher dose of ZnSO₄ gave higher yield components. The results showed that the seed yield was greater in 0.4% among Zinc doses. An experiment was conducted by Hossain *et al.*, (2016), at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi during the period from November 2013 to April 2014 to study the effect of boron and zinc on the growth and yield of chickpea. It has been reported that Zinc showed significant effect on almost all the yield attributes and yield of chickpea. The highest seed yield (1.742 t/ha) was obtained from 4 kg Zn ha and lowest one (1.325 t/ha) was found in control treatment. The highest plant height, number of primary branches/plant, number of secondary branches/plant, number of pod/plant, 1000-

seed weight, stover yield and biological yield were obtained from the application of 4 kg Zn/ha. Control treatment gave the lowest result regarding all these parameters. Zinc doses exerted significant influence on seed yield of chickpea. From the result of the experiment we can see that the highest seed yield was obtained from the application of 4 kg Zinc/ha and the lowest seed yield was obtained from control treatment. A field experiment was conducted by Balai *et al.*, (2017), at Agronomy farm, College of Agriculture, Bikaner during Rabi, 2009-10 and it was reported that increasing dose of zinc up to 6 kg/ha significantly increased the yield (grain, straw and biological yield). it was also found that the numbers of seed per pod increase significantly in same manner of pods per plant due to application of 6.0 kg Zn/ha over control and 3.0 kg Zn/ha by 21.16 and 7.79 per cent, respectively. Application of 6.0 kg Zn/ha produced significantly higher seed yield (1409.92 kg/ha), straw yield (2335.00 kg/ha) and biological yield (3744.92 kg/ha), which was significantly superior of the rest of treatments.

Effect of zinc fertilization on quality parameters

Sakal *et al.*, (1980) corroborated that zinc uptake by seed and stover of chickpea progressively increased with Zn foliar application. Enania and Vyas (1994) reported that the application of zinc upto 7.5 kg/ha significantly increased the Zn uptake by chickpea crop. This might be due to the fact that increasing levels of zinc increased its concentration in the soil solution which intern increased the absorption of zinc by plants in calcareous soils of Udaipur. Mehdi *et al.*, (1990) reported that the relative effectiveness of Zn sources decreased in the following order: Zn-EDTA > Zn(NO₃)₂ > (NH₄)₂ZnO₂ > ZnSO₄ > ZnCl₂. Singh *et al.*, (1992) reported that the concentration and plant uptake of Zn

were increased by Zn application in chickpea plant. Singh *et al.*, (1997) opined that application of 5 kg Zn ha⁻¹ has significantly increased that the seed protein yields of pulses over control. Srivastava *et al.*, (1999) also studied the comparative efficiency of different sources of Zn for lowland rice production. They reported that Zn-EDTA was the most efficient source of Zn for lowland rice production. Conducted studies by Khan *et al.*, (2003) in Australia on effect of Zinc fertilization on grain yield and seed Zn content in chickpea showed that increasing the soil zinc from 0.1 $\mu\text{g Zn/g}$ to 2.5 $\mu\text{g Zn/g}$ increased the mean seed Zn concentration from 8.5 to 46. $\mu\text{g Zn/g}$ in seed of chickpea. They also reported that largest portion of applied Zinc was found in the seeds of chickpea, which can be a beneficial nutritional trait for human nutrition. Akay A. (2011) studied the effect of zinc fertilizer applications on different chickpea varieties and the most suitable zinc application dose were investigated under the field conditions in May to September of 2003 and 2004. The results showed that the chlorophyll content in the leaves showed a significant difference among the varieties for both years ($P < 0.01$). The values of Phosphorus, phytic acid and Zn contents in the seed and the Zn content in the leaf of ILC-482 variety were found to be higher when compared with other varieties Zhao *et al.*, (2011) reported that the Zn fertilization significantly increased the amount of soil diethylene tri amine penta acetic acid-Zn (DTPA-Zn), whereas there was no significant effect on Zn concentration in grain. Furthermore, the utilization rate of Zn fertilizer was only 0.98%, 0.64%, 0.29%, and 0.14% with treatments of 7.5, 15, 30, and 45 mg Zn/ha, respectively. In contrast, the hydroponic experiment showed that both foliar spray and Zn supplied to roots significantly increased Zn concentration in grain, with the greatest concentration found in shoots. Results suggested that lower

absorption and translocation were the inhibitory factors to increase grain Zn concentration in calcareous soil. Studies Conducted by Pathak *et al.*, (2012), in Lucknow, to see the effect of zinc foliar application on improving plant yield and seed zinc content for human consumption and reported that Zinc foliar application improved not only the boldness and vigor of seeds in zinc-deficient plants, but also the seed zinc content in zinc-deficient seeds as well as the sufficient ones. There was an increase in Zn concentration in the leaves and seeds after Zn foliar application to Zn deficient as well as Zn sufficient plants. Zn concentration increased from 10 $\mu\text{g/dry weight}$ in Zn deficient seeds to 35 $\mu\text{g/g dry weight}$ in Zn deficient foliar seeds. Roy *et al.*, (2013) reported that application of Zn @ 0, 5.5 kg, 22 kg Zn/ha, 0.1% Zn foliar application and 5.5 kg Zn + 0.1% Zn spray, increased the yield, concentration and its uptake in seed and straw in all the green gram genotypes. Maximum Zn concentration in straw and seed (5.48 and 3.5 folds over control) was achieved when combined application of soil + foliar was made. Soil + foliar application of Zn increased the seed crude protein by 26.9% over control. A field experiment was conducted by Gowda *et al.*, (2014), during kharif 2012-13 at the Agricultural College Farm, Raichur, to study the response of pulses to soil application of micronutrients and foliar spray of macronutrients on yield, yield components, protein yield and economics. The results revealed that the soil application of ZnSO₄ @ 25 kg/ha along with foliar spray of 19:19:19 @ 0.4 % recorded significantly higher protein content (22.47%), protein yield (288.75 kg/ha), higher leaf area per plant (27.23 dm² /plant) and higher chlorophyll content (66.43 %). Paramesh *et al.*, (2014) advocated that 25 kg ZnSO₄.7H₂O/ha soil has recorded significantly higher seed zinc (101 g/ha), protein (9.0%) and protein yield (379 kg/ha) in maize crop, but it was at par with

12.5 kg ZnSO₄.7H₂O/ha soil + 0.5 % ZnSO₄.7H₂O foliar spray and the lower protein, protein yield was found in the control plots. Studies conducted by Shivay *et al.*, (2014) at IARI, New Delhi, to study the effect of varieties and levels of Zinc (Zn) on protein content, Zn and nitrogen uptake by chickpea (*Cicer arietinum* L.) and reported significant enhancement in Zn concentration in grains and straw. The study further indicates that there was high Zinc uptake, protein yield and protein content in chickpea grains over control treatments. It was found that each successive level of Zn application increase Zn concentration in Chickpea straw upto 7.5 kg Zn/ha. Zn concentration in chickpea grain increased from 38.6 mg/kg in no Zn (check) to 48.4 mg/kg with an application of 7.5 kg Zn/ ha.

Dadkhah *et al.*, (2015) studied the effect of water deficit stress and foliar application of zinc on physiological characteristics of chickpea in field crop research station of University of Mohaghegh Ardabili. In this study proline, lysine, methionine, soluble sugars, and protein content were measured. The result showed that Spraying 6 kg/ha zinc sulphate also enhanced the amount of proline, soluble sugar and osmotic potential of Chickpea plants. Fasaei *et al.*, (2015) studied the effect of Zinc treatments on the growth and nutrient composition of chickpea in a greenhouse and reported that the application of Zn increased mean Zn uptake in chickpea shoot. Application of 10 mg Zn/ kg increased mean Zn uptake of aboveground tissues by 73% and 123% respectively. Kayan *et al.*, (2015) conducted an experiment on Chickpea crop in Turkey to evaluate the effect of foliar application of Zn and reported that increased zinc doses caused an increase in Zinc content of seed and also concluded that foliar application of Zinc resulted in an increase in seed mineral content viz. Zn, Fe, P and N contents in seed of Chickpea. The results also

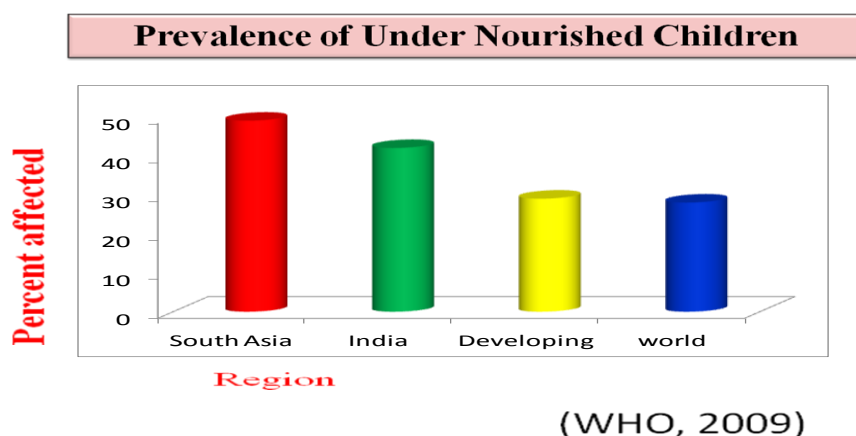
showed that the highest Zn, Fe and P content in seed was detected in 0.6%. To study the effects of foliar application of zinc on yield, yield components and grain quality of chickpea (*Cicer arietinum* L.), Shirani *et al.*, (2015), conducted two experiments, one in autumn and the other in spring were conducted at Research Farm, Shahrekord University in 2009-2010 growing season and it was concluded that the Foliar application of zinc sulphate significantly increased Zn content of grains. A field experiment was conducted by Singh *et al.*, (2015), during two consecutive *rabi* seasons of 2012-13 and 2013-14 at New Research Farm, ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, to study the effect of diverse combinations of foliar fertilization on growth, yield attributes, yield, nutrient partitioning and nutritional enrichment of chickpea. It was concluded that foliar fertilization with zinc significantly improved the concentration in stem, leaf and root of the chickpea plant. Further, foliar spray with zinc significantly enhanced concentration of protein, zinc and iron, respectively over no spray. It was reported that without Zn spray, Zn concentration in grain recorded only 27.12 mg/kg but when zinc was sprayed the Zn concentration improved (32.48 mg/kg).

Experiment was conducted by Choudhary *et al.*, (2016), during *rabi* seasons of 2012-13 and 2013-14 to study the effect of zinc fertilization on quality, nutrient uptake, profitability and moisture use indices of chickpea under limited moisture conditions. It was found that direct application of 5.0 kg Zn/ha significantly improved the protein content in grain during 2013-14 and protein yield, total uptake of N and P over lower levels. Conducted experiment by Balai *et al.*, (2017), at Agronomy farm, College of Agriculture, Bikaner during *Rabi*, 2009-10 reported that the application of 6 kg Zn/ha recorded significant increase in chlorophyll

content in Chickpea plants. In an experiment conducted by Kharol *et al.*, (2014), to study the effect of sulfur and zinc on yield, quality and nutrient content and uptake by chickpea (*Cicer arietinum* L.) during *rabi* season of 2011-2012. The results indicated that application of increasing levels of sulfur and zinc increased the grain yield, protein content, nutrient content and nutrient uptake of chickpea. Field experiments were conducted by Hidoto *et al.*, (2017) at three locations with Zn deficient soils in southern Ethiopia during 2012 and 2013 cropping seasons to evaluate

the effects of Zn fertilization strategies and varietal differences on Zn content and plant performance of chickpea (*Cicer arietinum* L.). The result showed that Zinc application strategy significantly influenced both grain and straw Zn concentrations. Accordingly, Zinc foliar application increased grain Zn content by 21 and 22% over Zn soil application and seed priming, respectively. Moreover, foliar application resulted in 383 and 437% increase in straw Zn content over soil application and seed priming methods, respectively.

Fig.1



Effect of zinc fertilization on relative economics

Naik and Das (2008) reported that the highest cost-benefit ratio was 1.71 with basal application of 0.5 kg Zn/ha as Zn-EDTA. With regards to modes of application of ZnSO₄, split application of 10 and 20 kg Zn/ha as ZnSO₄ resulted in a higher cost-benefit ratio of 1.32 and 1.21, respectively, over the corresponding basal applications. However, basal application of 1.0 kg Zn ha⁻¹ as Zn-EDTA resulted in a higher cost-benefit ratio of 1.69 over its corresponding split application. Yadav *et al.*, (2010) reported that the economic return was highest at the 1.0%

level in the case of ZnSO₄, and at the 2.0% level in case of ZnO. Further, 1.0% ZEU (ZnSO₄) application gave much higher economic return than 2.0% ZEU (ZnO). Experiment was conducted by Ramaprasad *et al.*, (2011) on clay loam soil in farmer’s field of Cheluvanuppalapadu village, Nagulappalapadu Mandal, Prakasam (Dt.), Andhra Pradesh during *rabi* 2007-08 to study the effect of soil and foliar application of Zinc sulphate on seed yield nutrient uptake and economics of kabuli chickpea (Cv LBeG-7). It was reported that application of 25Kg ZnSO₄/ha through soil in combination with 0.5% ZnSO₄ foliar spray twice (at 45 and 55 DAS) recorded highest B:C ratio 1: 2.98 and

net returns (Rs. 59,037 per hectare). Studies was conducted by Shivay *et al.*, (2014) at IARI, New Delhi, on effect of Zinc application on yield, profitability, protein content and Zinc uptake by Chickpea, to assess the economic feasibility of the Zinc application over control treatments and found that there was significant enhancement of gross and net returns over control by way of increasing seed yield of chickpea crop. The study also revealed that benefit: cost ratio as well as net profitability of Zn applied treatments was also high over control treatments. Ghasal *et al.*, (2015) reported a strong positive correlation between yield attributes (effective tillers/hill, fertility percentage and grains/panicle) and yield of rice. For net returns and benefit: cost ratio viewpoint, application of 2.5 kg Zn/ha ($ZnSO_4 \cdot 7H_2O$) + 0.5% FS at maximum tillering and panicle initiation proved better and gave the highest net returns.

A field experiment was conducted by Jat *et al.*, (2015) during Rabi 2010–11 at farmers' fields in Raniwas village of Dausa district of Rajasthan, which falls in agroclimatic zone IIIa (Semi arid eastern plain zone) and it was reported that the highest gross returns (Rs 35420/ha), Net returns (Rs 15238/ha) and B:C ratio (1.75) were recorded with the treatment T4 (500 ppm thiourea+ 0.2% zinc sulphate (mixed solution) spray at vegetative and reproductive stage) while in Treatment T1 (control) the gross returns (Rs 28420/ha), net returns (Rs 12020/ha) and B:C ratio (1.73) were recorded. Kumar *et al.*, (2015) conducted a field experiment at Varanasi during the 2 consecutive pre-kharif (rainy) season of 2012 and 2013 on baby corn with three zinc levels (0, 5 and 10 kg Zn/ha) and observed that 5 and 10 kg Zn/ha though remained comparable registered significantly higher net returns and benefit: cost ratio over the control. Singh and Shivay (2015) further observed that application of EDTA-chelated

Zn (12% Zn) gave highest gross returns (US \$1,713.68 and US \$2,018.30/ha), but significantly lower net returns (US \$782.77 and US \$995.58/ha) compared to other Zn sources during 2009 and 2010, respectively.

The highest values of net returns were obtained by $ZnSO_4 \cdot 7H_2O$ (21% Zn) application (US \$1,068.96 and US \$1,250.22/ha), which was significantly higher than all other Zn sources, resulting into a higher net B:C ratio of 1.88 and 1.89 during both years, respectively. Singh *et al.*, (2015a) conducted the field experiment at research farm, Raja Balwant Singh College, Bichpuri, Agra, Uttar Pradesh by 4 levels of K_2O and 4 levels of Zn (0, 3.0, 6.0 and 9.0 kg/ha) in factorial experiment laid out in randomized complete-block design. They found that application perspective, the maximum net returns (49000.1 Rs/ha) and benefit: cost ratios (1.97) were obtained with 9 kg Zn/ha which was statistically non- significant with 6 kg Zn/ha. No Zn treatment resulted in the lowest net returns and benefit: cost ratio due to lower grain and straw production.

To study the effect of moisture conservation and zinc fertilization on quality, nutrient uptake, profitability and moisture use indices of chickpea under limited moisture conditions, a field experiment was conducted by Choudhary *et al.*, (2016), during rabi seasons of 2012-13 and 2013-14. It was reported that under zinc fertilization, direct application of 5.0 kg Zn/ha significantly improved the net returns and production efficiency during both the years of investigation over lower levels. Conducted experiment by Balai *et al.*, (2017), at Agronomy farm, College of Agriculture, Bikaner during Rabi, 2009-10 reported that the application of 6 kg Zn/ha recorded higher net returns (Rs. 21810.83 /ha) and higher B:C ratio (2.62).

Effect of Iron fertilization on

Effect of Iron fertilization on growth parameters

Effect of iron fertilization on the plant height of chickpea cultivars

Mahriya and Meena (1999) while working on cowpea, at Jobner (Rajasthan), concluded that growth characters of plant like plant height were increased with the application of Fe foliar application over control treatments. Field experimentation conducted by Balachander *et al.*, (2003) to study the effect of micronutrients on yield of gram reported that the application of Fe through ferrous sulphate significantly increased the plant height of chickpea over control. Experiments on chickpea were carried out by Gizawy *et al.*, (2004), during the two winter seasons of 2001/02 and 2002/03 at the Experimental Center, Faculty of Agriculture at Moshtohor, Zagazig University and it was reported that spraying chickpea plants with Fe surpassed the tap water (control) in plant height of chickpea over rest of the treatments. Fasaei *et al.*, (2013) conducted a greenhouse experiment to study the effect of iron treatments on the growth and nutrient composition of chickpea and reported that application of iron significantly increased plant height of chickpea plant over control.

Effect of iron fertilization on the leaf area index of chickpea cultivars

Mevada *et al.*, (2005) reported improvement in the growth parameters like leaf area index by the application of 1.0 kg chelated iron/ha along with RDF over the 2.0 kg chelated iron and control in pulse crop. A field experiment was carried out by Janmohammadi *et al.*, (2012), to study the effect of micro-nutrient (iron) application on yield and yield component of chickpea under irrigated

conditions during 2010 growing season at experimental farm of the University of Tabriz. The results showed that application of Fe has significant effect on leaf area index, so that the lowest leaf area was recorded for control plants. Experiment conducted by Fasaei *et al.*, (2013), to study the effect of iron treatments on the growth and nutrient composition of chickpea, revealed that application of iron significantly increased leaf area index of chickpea plant over control. A field experiment was conducted by Jha *et al.*, (2015), at the instructional farm of Rajasthan College of Agriculture, Udaipur, Rajasthan during kharif season of 2013 to study the effect of organic and inorganic sources of nutrients on yield and economics of blackgram. The result indicated that application of 100 % RDF + Zn + Fe (N:P:K-20:30:15 kg/ha + ZnSO₄ 5 kg/ha + FeSO₄ 5 kg/ha) recorded significantly highest leaf area index respectively over rest of the treatments.

Effect of iron fertilization on the dry matter accumulation of chickpea cultivars

Balachander *et al.*, (2003) while studying the effect of micronutrients on yield of gram reported that the application of Fe through ferrous sulphate significantly increased the dry matter production of chickpea over control. Studies on chickpea were carried out by Gizawy *et al.*, (2004), during the two winter seasons of 2001/02 and 2002/03 at the Experimental Center, Faculty of Agriculture at Moshtohor, Zagazig University and it was reported that spraying chickpea plants with Fe resulted in increased dry matter production as compared to the plants treated with no Fe. Singh *et al.*, (1998) working on mungbean under clay laoms soils of Kanpur found that the dry matter accumulation was significantly increased with ferrous sulphate application. Mahriya and Meena (1999) while working on cowpea, at Jobner (Rajasthan), concluded that growth characters of plant like dry matter

accumulation were increased with the application of Fe. Balachander *et al.*, (2003) while studying the effect of micronutrients on yield of gram reported that the application of Fe through ferrous sulphate significantly increased the dry matter production of chickpea over control.

Studies on chickpea were carried out by Gizawy *et al.*, (2004), during the two winter seasons of 2001/02 and 2002/03 at the Experimental Center, Faculty of Agriculture at Moshtohor, Zagazig University and it was reported that spraying chickpea plants with Fe resulted in increased dry matter production as compared to the plants treated with no Fe.

Effect of Iron fertilization on Physiological parameters

Khan *et al.*, (2014) conducted field experiments to study the influence of different levels of Iron on the nodulation, nitrogen fixation and yield of chickpea genotypes, at Malakandher farm, University of Agriculture, Peshawar. The data pertaining to days to flowering showed that maximum number of days (138 days) for flowering were recorded in control, while the minimum numbers of days to flowering (133 days) were recorded where Fe 2kg/ha were applied in both genotypes of chickpea.

A field experiment was conducted by Tayade *et al.*, (2016), at Horticulture Section, College of Agriculture, Nagpur (Maharashtra) India, during 2010–2011.

The results of the experiment showed significant differences in growth, flowering, yield and quality parameters of annual chrysanthemum due to application of zinc and iron. It was found that days to 50% flowering were recorded significantly higher with application of 0.3% zinc and 0.3% iron.

Effect of zinc and iron fertilization on the yield and yield attributes of chickpea cultivars

Duraisamy *et al.*, (2001) revealed that the combined application of 0.5% FeSO₄ and 0.10% MoO₄ recorded higher grain and haulms yield of 634 and 934 kg/ha over control (467 and 745 kg/ha) in pulse crops under red loamy sandy soil. Reddy *et al.*, (2007) reported that the application of chelated iron at 3.0 kg/ha along with RDF was recorded higher grain yield of 2.2 tones/ha over the control (1.9 tones/ha) followed by 2.1 tones/ha by application of 2.0 kg/ha in legumes under *rainfed* conditions in Vertisols of Andhra Pradesh. Umamaheswari *et al.*, (2002) reported that there is increase in the pods/plant, seeds/pod and 100 seed weight in pulse crop by increasing level of application of ferrous sulphate from 2.5 to 5 kg/ha under sandy loam soils of Varanasi. Balachander *et al.*, (2003) while studying the effect of micronutrients on yield of gram reported that the application of Fe through ferrous sulphate significantly increased the grain yield of chickpea over control. Experiments on chickpea were carried out by Gizawy *et al.*, (2004), during the two winter seasons of 2001/02 and 2002/03 at the Experimental Center, Faculty of Agriculture at Moshtohor, Zagazig University and it was reported that Spraying chickpea plants with Fe surpassed the tap water (control) in number of seeds/plant, weight of pods/plant, seed index, seed yield/plant, seed, straw and biological yield. Salam *et al.*, (2004) reported that there is increase in the pods/plant, seeds/pod, seed/plant, pod weight/plant and seed weight/plant in legumes by increasing level of application of ferrous sulphate from 1.0 to 2.0 kg/ha along with NPKS (20:50:20:20 kg/ha). Mevada *et al.*, (2005) reported improvement in the growth parameters by the application of 1.0 kg chelated iron/ha along with RDF over the 2.0

kg chelated iron and control in pulse crop. Ashoka *et al.*, (2008) reported that the application of 25 kg ZnSO₄ + 10 kg FeSO₄ + 35 kg FYM/ha along with RDF recorded higher grain yield of 14.34 q/ha over the control (8.61 q/ha) in chickpea in Vertisols of Karnataka. Conducted field experiments by Patel *et al.*, (2008), during kharif seasons of 2002, 2003 and 2005 to study the effect of zinc and iron on yield and yield attributes of rainfed pulses at Main Pulses Research Station, S.D. Agricultural University, Sardarkrushinagar on loamy sand soil. It was reported that spraying of 0.5% FeSO₄ and 0.5% ZnSO₄ at 25 DAS gave significantly higher straw yield of cowpea over control, 0.5% FeSO₄ spray at 25 DAS and 0.5% FeSO₄ spray at 45 DAS but was at par with the remaining treatments. Kumar *et al.*, (2009) conducted an experiment at Kanpur and reported that the branches per plant, number of pods per plant, number of grains per pod and test weight significantly increased with levels of Fe upto 10 kg/ha and enhanced the grain yield of chickpea by 17.3% over control. Similar trend in straw yield response was also recorded. Patel *et al.*, (2009) reported that the combined spraying of 0.5% FeSO₄ and 0.5% ZnSO₄ spray at 25 and 45 DAS gave significantly higher seed and straw yield of pulse crop (1404 and 1975 kg/ha) over control. Gupta *et al.*, (2012) reported that the application of 2.0 g ammonium molybdate + 1.0 g FeSO₄/kg seed treatment + *Rhizobium* + PSB along with RDF recorded higher plant height (40.32 cm), branches/plant (5.86) and plant dry weight/plant at 90 DAS (5.83 g) over the control in chickpea under medium black Vertisol. A field experiment was carried out by Janmohammadi *et al.*, (2012), to study the effect of micro-nutrient (iron) application on yield and yield component of chickpea under irrigated conditions during 2010 growing season at experimental farm of the university of Tabriz. The results showed that application

of Fe has significant effect on plant height, so that the lowest height was recorded for control plants. Number of primary and secondary branches per plant also increased with application of the Iron application. Khan *et al.*, (2014) conducted field experiment during 2011-12 at Malakandhar Farm, University of Agriculture, Peshawar, to study the influence of different levels of Iron on the yield of chickpea genotypes and the results showed that maximum yield and yield parameters were observed in those treatment plots where Fe 2.0 kg/ha were applied. It was also reported that maximum shoot biomass 6434 kg/ha were found in treatment plot where Fe 2 kg/ha were applied while the minimum shoot biomass 4375 were recorded in control (where no Fe were applied). It showed that Fe application had positive effect on the production of shoot biomass. Also, the maximum grain yield of 465 kg/ha were obtained for treatment receiving Fe 2.0 kg/ha, while minimum grain yield of 370 kg/ha were obtained in control. Pingoliya *et al.*, (2014) studied the effect of iron (Fe) on growth and yield attributes of chickpea (*Cicer arietinum* L.) was studied during *rabi* season of 2010-2011 with Fe (control, 2.5, 5 and 7.5 kg Fe/ha) and it was found that with 5 kg Fe/ha plot, yield attributes like plant height, branch/plant, pods/plant, seed/pod and test weight were significantly improved compared to rest of the treatments. It was also observed that the increasing levels of iron up to 5.0 kg Fe/ha increased the plant height significantly. However, maximum plant height (51.53 cm) at harvest was recorded with the application of 7.5 kg Fe/ha but found at par with 5.0 kg Fe/ha. The application of 2.5, 5.0 and 7.5 kg Fe/ha significantly increased the plant height to the tune of 2.3, 12.11 and 19.15 per cent, respectively over control (43.33 cm). Application of 5.0 kg Fe/ha significantly increased seed yield over control and 2.5 kg Fe/ha by 30.19 and 19.17 per cent, respectively. Fasaei *et al.*, (2015) conducted a

greenhouse experiment to study the effect of iron and zinc treatments on the growth and nutrient composition of chickpea and reported that application of Iron significantly increased mean Fe concentration in chickpea plant and also concluded that the use of Fe and Zn efficient genotypes should be considered as an appropriate practice for chickpea grown on calcareous soils low in available Fe and Zn. A field experiment was conducted by Jha *et al.*, (2015), at the instructional farm of Rajasthan College of Agriculture, Udaipur, Rajasthan during kharif season of 2013 to study the effect of organic and inorganic sources of nutrients on yield and economics of blackgram. The result indicated that application of 100 % RDF + Zn + Fe recorded significantly number of pods, number of seeds, seed yield, straw yield, biological yield, harvest index, respectively over rest of the treatments but it was at par with 100% RDF, 50% RDF+50% RDN through FYM and FYM 4 t/ha. The seed yield of gram significantly increased by 8.75 over 100% RDF.

Effect of zinc fertilization on quality and uptake

Kumpawat *et al.*, (1994) while studying the effect of micronutrients on the protein content of gram reported that the application of 20kg FeSO₄/ha significantly increased the dry weight of nodules, seed protein content and seed yield over control treatments. Shukla *et al.*, (1994) from Allahabad, India while working on effect of Fe and Zn in Chickpea crop reported that application of 25 and 50 kg FeSO₄ /ha to chickpea crop resulted in increased number of nodules per plant, dry weight of root nodules, leg haemoglobin content of root nodules and rate of N₂ fixation as compared to control treatment that ultimately increased the growth and yield of Chickpea crop. It was also observed that increase in Fe concentration in seeds of Chickpea with increasing levels of FeSO₄ up

to 50 kg/ha over control. Mahriya *et al.*, (1999) conducted a field trail at Jobner (Rajasthan), and they concluded that all the growth characters as well as protein content in seed were increased with the application of 4 kg Fe/ha. Duraisamy *et al.*, (2001) reported that spraying of 0.5% FeSO₄/ha significantly increased the iron content in grain (434 g/ha) and combined soil application of 10 kg FeSO₄/ha and increased the iron content in haulms (624 g/ha) over the control in gram. Patel *et al.*, (1993) conducted a field trail on calcareous soils of Gujarat revealed that foliar spray of one percent FeSO₄ +0.1% citric acid significantly increased concentration of Fe in legume leaves by 160.78 % at 60 days of crop over control. Gizawy *et al.*, (2004) carried out two field experiments on chickpea during the two winter seasons of 2001/02 and 2002/03 at the Experimental Center, Faculty of Agriculture at Moshtohor, Zagazig University and it was observed that spraying chickpea plants with Fe increases the protein yields and seed P content. Kumawat *et al.*, (2006) observed that the application of 25 kg FeSO₄/ha in pulse crop increased the activities of the catalase, guaiacol peroxidase synthesis of chlorophyll and active Fe content of green leaves over lower doses of FeSO₄ and controlled treatment. Sahu *et al.*, (2008) also reported that the application of FeSO₄ at the rate of 2kg/ha significantly increased the protein content of the seed and also the grain yield of Chickpea crop. This might be due to increased nitrogenase activities and more nitrogen fixation at lower doses. Study was carried out by Janmohammadi *et al.*, (2012) during 2010 growing season at experimental farm of the university of Tabriz, to study the effect of bio-fertilizer and micro-nutrients (iron and zinc) application on yield and yield component of chickpea under irrigated conditions, where it was found that positive effects of micro-nutrients application on morphological traits were more predominant than bio-fertilizer inoculation. It was also

observed that the highest chlorophyll index was recorded in plants that had been received Fe, as their chlorophyll index was 26 % higher over control. Conducted field experiment by Khan *et al.*, (2014), during 2011-12 at Malakandhar Farm, University of Agriculture, Peshawar, to study the effect of Iron on nodulation and nitrogen fixation of Chickpea genotypes reported that with increasing levels of Fe in soil, the concentration of Fe in plant leaves significantly increased at flowering stage. Moreover, the study revealed that application of Fe 2.0 kg/ha is important which plays a significant role in getting the maximum nodules and nitrogen concentration in chickpea genotypes. It was observed that the maximum iron concentration was obtained for the treatment receiving Fe 2.0 kg/ha which is 276µg/g over control treatments. Results showed that increased concentration of Iron in plants may be due to the positive interaction within legume plants. Field experiment was conducted by Pingoliya *et al.*, (2015), to see the effect of phosphorus (P) and iron (Fe) on protein content in grain and chlorophyll content in leaf of chickpea (*Cicer arietinum* L.). The study revealed that application of Fe also increased the protein content with increasing level from 0 to 7.5 kg Fe/ha. It was lower (23.45%) in control and higher in highest level, which was at par with 5 kg Fe/ha. In the chlorophyll content maximum increased was observed in 7.5 kg Fe/ha over 0, 2.5 and 5 kg Fe/ha. It was observed that Iron application at 2.5 and 5 kg Fe/ha significantly increased the protein content to the tune of 8.07 and 18.58 per cent, respectively over control (19.69 per cent) but are found at par with 7.5 kg Fe/ha. However, maximum protein content in grain was found at the level of 7.5 kg Fe/ha. The result also observed that application of 7.5 kg Fe/ha significantly increased the chlorophyll content in leaf to the extent of 6.75, 5.85 and 4.97 per cent, respectively over control, 2.5 and 5 kg

Fe/ha. Conducted field experiment by Singh *et al.*, (2015), during two consecutive *rabi* seasons of 2012-13 and 2013-14 at New Research Farm, ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, to study the effect of diverse combinations of foliar fertilization on growth, yield attributes, yield, nutrient partitioning and nutritional enrichment of chickpea reported that foliar spray with iron significantly enhanced concentration of protein, zinc and iron, respectively over no spray. It was observed that iron spray enhanced iron concentration in chickpea grain by 21.9 per cent, respectively. It was also found that application of iron foliarly might helped in better photosynthesis and photosynthate partitioning to yield attributing characters which resulted in higher sink size (Ferrandon and Chamel, 1988; Ghasemi- Fasaei *et al.*, 2005; Shivay *et al.*, 2013). Khalid *et al.*, (2015) conducted a pot study in University of Agriculture, Faisalabad, Pakistan, to determine the effect of bio fortification of iron in chickpea and it was observed that application of FeSO₄ significantly improved the Fe content upto 100 and 173% in grain and shoot respectively, as compared to control.

Effect of Iron fertilization on Relative Economics

Field experiments were conducted by Anitha *et al.*, (2005), under AICRP on Arid Legumes during *kharif* seasons 2001- 2002 to elucidate the response of pulses to zinc and iron fertilization for augmenting the crop productivity. It was observed that combined spraying of 0.5% FeSO₄ and 0.5% ZnSO₄ at 45 DAS proved most effective and increased the seed yield by 43.09 per cent when compared with control followed by combined spraying of 0.5% FeSO₄ and 0.5% Znso₄ at 25 DAS (40.14%). The net return and benefit cost ratio also followed the same trend. A field experiment was conducted by Patel *et al.*,

(2008), during *kharif* seasons of 2002, 2003 and 2005 to study the effect of zinc and iron on yield and yield attributes of *rainfed* pulses at Main Pulses Research Station, S.D. Agricultural University, Sardarkrushinagar on loamy sand soil. The results revealed the the highest net return of Rs.13, 114 per ha was obtained when the crop was fertilized with soil application of 25 kg ZnSO₄ per ha followed by the foliar spray of 0.5% FeSO₄ and 0.5% ZnSO₄ at 25 DAS (Rs. 11,038/ha) and 0.5% ZnSO₄ at 25 and 45 DAS (Rs. 10,978/ha). Field experiment conducted by Singh *et al.*, (2014), at the Punjab Agricultural University, Ludhiana, during the rainy (*kharif*) season of 2010 and 2011 with 13 treatments in randomized block design, to determine the effect of foliar feeding of micronutrients on growth and yield of direct-seeded basmati rice (*Oryza sativa* L.). The result showed that 4 sprays of 1.0% solution of FeSO₄ at 40, 50, 60 and 70 days after sowing DAS gave higher net returns and benefit: cost ratio over the control. Conducted field experiments by Jha *et al.*, (2015), at the instructional farm of Rajasthan College of Agriculture, Udaipur, Rajasthan during *kharif* season of 2013 to study the effect of organic and inorganic sources of nutrients on yield and economics of gram. The result indicated that application of 100 % RDF + Zn + Fe (N:P:K- 20:30:15 kg/ha + ZnSO₄ 5 kg/ha + FeSO₄ 5 kg/ha) recorded significantly gross return, net return and B: C ratio, respectively over rest of the treatments. Application of 100% RDF + Zn+ Fe and 100% RDF significantly increased the net return and benefit cost ratio of gram over control. The net return of gram significantly increased by 11.22 per cent, respectively over 100% RDF. Lashkari *et al.*, (2008) found that the cultivation of cauliflower cv. SNOWBALL-16 was found to be more beneficial and economical with foliar sprays of Zinc (ZnSO₄) and Iron (FeSO₄) in nine treatment combinations considering 3 levels of Zn (0.0,

0.5 and 1.0%) and 3 levels of Fe (0.0, 0.5 and 1.0%) during *rabi* season of the year, 2002-03. Significantly highest marketable yield with highest net return was obtained with combine foliar sprays of zinc and iron at 0.5% concentration each.

In conclusion the study conducted for demonstrating the review of literature of last three decades in front of the scientists of across the globe clearly indicated that Unlike plants, humans also require essential micronutrients and protein for normal physiological functions of the body and general health. Due to low concentration of micronutrients and protein in the staple food, billions of population is lacking sufficient daily intake of micronutrient and protein in their diet sometimes called '*hidden hunger*'. Micro nutrient malnutrition is a serious problem to human health throughout the world, primarily in resource limited countries. The micronutrients most commonly associated with human health problems on a global scale include iron, zinc and iodine. Humans require at least 22 mineral elements for their wellbeing. These can be supplied by an appropriate diet. However, it is estimated that over 30 percent of population is zinc (Zn) deficient and rest with other micronutrients. Among micronutrients, Zn deficiency is occurring in both crops and humans. Zinc deficiency is currently listed as a major risk factor for human health and cause of death globally. According to an estimate of World Health Organization (WHO) during 2015, around two billion people are being suffered with iron and zinc deficiencies and its deficiency ranks 11th among the 20 most important factors in the world and 5th among the 10 most important factors in developing countries like India. Zn deficiency is widespread in chickpea growing region of the world and is most prevalent among the micronutrients. In the sequence of micronutrient malnutrition; iron is also

playing a vital role. The agronomic bio-fortification of zinc and iron in chickpea under *rainfed* areas for poor and under nourished masses of south East Asia is an important and easy tool to fight against the nutritional security.

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